Editorial for the special edition on DYAMOND: The DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains

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A revolution is in the making. For years climate science has had to parameterize energy transports in the climate system's most crucial dimension, that which spans Earth's atmosphere, from the surface to space. A lack of computational power to resolve the transient dynamics of the processes that regulate the vertical exchange of energy, and a lack of understanding of how and if their statistics relate to the large-scale quasi-horizontal evolution of the atmosphere, is at the source of many of the systematic biases that plague climate modelling. While not critical for understanding how warming responds to greenhouse gas concentrations, these biases substantially hinder our ability to understand how climate changes with warming – paralyzing efforts to assess warming risks and devise adaptation measures. This special edition, focusing on an analysis of the DYAMOND – the DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains – simulations provides a glimpse into the status of a new generation of models, ones that are designed to leverage advances in computing to overcome the shortcomings of the previous generations of models. DYAMOND, the first intercomparison of global storm-resolving models, was noteworthy less for what it did – Masaki Satoh and Hirofumi Tomita developed and ran the first such models nearly twenty years ago – than for who did it and how they did it. Rather than just one short simulation by a single group, simulations of forty days were performed at many resolutions, by many groups, and the results were opened – thanks to the EU Horizon 2020 ESiWACE project (https://www.esiwace.eu) coordinated by the German Climate Computing Center (DKRZ, http://www.dkrz.de) – to analysis by anyone. What Satoh and Tomita showed was feasible has suddenly become practical. The papers in this special edition demonstrate this, and in so doing provide a snapshot of where we are and where we are going in what has become an international endeavor to strengthen the scientific foundations of climate modelling.

Already, just from a sampling of the collected papers, and subsidiary studies published in other journals, some broad conclusions can be drawn. One is that global storm-resolving models robustly ameliorate many of the biases in the representation of deep convection, at least in simulations whose sea-surface temperatures are prescribed (Stevens et al. 2020; Bao and Stevens 2021; Judt et al. 2021; Roh et al. 2021). Papers in this special issue document marked improvements in the spatial, temporal, and intensity distribution of precipitation, even so far as capturing signals from subtle forcings, such as the semi-diurnal cycle (Arnold et al. 2020; Inoue et al. 2021). Another finding that cuts across many studies is that sensitivity to resolution at storm-resolving scales is informative – refinements of resolution suggest that at storm-resolving scales models are mostly on a convergent trajectory, and that where biases exist they can be understood in physical terms, rather than as the outcome of parameter choices and error compensation strategies (Hohenegger et al. 2020; Stevens et al. 2020). Global storm-resolving models are also showing promising predictive skill, for instance as herein demonstrated through predictions of the Boreal Summer Intra-Seasonal Oscillation (Shibuya et al. 2021). A forthcoming stream of the global storm-resolving operational model is provided (Dueben et al. 2020). Among these papers, Stevens et al. (2020) won the JMSJ Award in 2020.

Snapshots provided by this special edition of papers also highlight exciting scientific challenges that remain. Here and now is the question as to how to overcome the effects of inadequate resolution on mixing and cloud-microphysical processes (Stevens et al. 2020; Heim et al. 2021). Looming, just over the horizon, is the next big leap, to coupled models, and the question as to whether more physical representations of the atmosphere and ocean individually also lead to improved predictions when coupled together. This challenge is being taken up by DYAMOND (Boreal) Winter, a follow-up project. Looming behind the scenes is the considerable challenges exa-scale capability poses for workflow, from the staging and execution of the simulations to the management and analysis of their output. Here, however, computationally intensive approaches such as used in DYAMOND, and analysis frameworks it developed together with the ESiWACE project, are blazing trails through the computational landscape that will ease the way for all who follow, also for those using much less computationally intensive approaches.

We thank the following guest editors who handled the papers for review process: Chris Bretherton (University of Washington), Peter Dueben (the European Centre for Medium-Range Weather Forecasts), Cathy Hohenegger, Daniel Klocke (Max Plank Institute), Falko Judt (National Center for Atmospheric Research), Chihiro Kodama, and Akira Noda (Japan Agency for Marine-Earth Science and Technology).

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